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APPLICATION NOTE

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Keyboard/Display Scanning With Intel's MCS-48™ Microcomputers

John Wharton
Microcomputer Applications

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Related lntel Publications

"MCS-48 Microcomputer Family Users' Manual"

"MCS-48 Assembly Language Programming Manual"

Keyboard/Display Scanning With Intel's MCS-48™ Microcomputers

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INTRODUCTION

This application notes presents a software package for interfacing members of Intel's MCS-48™ family of single-chip microcomputers with keyboards and displays using a minimum of external components. Because of the similarity of the architectures of the various members of the family (the 8035, 8048, 8748, 8039, 8049,8021, and 8022 microcomputers; also the 8041 and 8741 universal peripheral interfaces in the UPI-41® family), the code included here could run with minor modifications on any member of the family.

Since keyboard and display logic can be just one of several functions handled by a microprocessor, the added cost of including these functions in a system is minimal. In fact, considering the extremely low cost of standard X-Y matrix keyboards and integrated displays, their use is often more cost effective than even a handful of discrete switches and indicators. Thus, the additional flexibility of keyboard input and display output can be added to inexpensive consumer products (such as games, clocks, thermostats, tape recorders, etc.), while producing a net savings in system cost.

Since each potential application will have its own unique combination of keys and display characters, the program is written so that very little modification is needed to interface it with a wide variety of hadware configurations. In general, the only changes required are within the set of initial EQUates at the beginning of the program.

Along with the basic software for driving a multiplexed display and/or scanning and debouncing an X-Y matrix of key switches, a collection of utility subroutines is also included for implementing the most commonly used keyboard and display utility functions, such as copying simple messages onto the display or determining the encoded value of each key in the key matrix. As a result of the versatile architecture and applications-oriented instruction set of the MCS-48 family, the entire package fits into about 250 bytes of internal program ROM or EPROM, leaving the rest of the ROM space for the program to cook the perfect piece of toast, or whatever. By tailoring the software to match a known hardware configuration, or by selecting only those functions needed for a given application, the program size could be even further reduced.

Since what is being presented in this application note is a software package, rather than the usual hardware1 software system design, the format of this note is somewhat different from most — it consists primarily of a long program listing reproduced in the following pages. For the most part, the listing is self-explanatory, with comments introducing each subroutine and major code segment. Some parts of this introduction are reproduced in the program listing itself, explaining the configuration of the prototype system. However, an additional bit of explanation would make the listing easier to understand, especially for those readers unfamiliar with the concept of multiplexed displays and keyboards.

In traditional digital system design, various hardware registers or counters were used to hold binary or BCD values which had to be conveyed to the user. The standard way of presenting this information was by connecting each register to a seven-segment encoder (such as the 7447) driving a single display character, as represented by Figure 1. Thus, two ICs, seven current limiting resistors, and about 45 solder joints were required for each digit of output. Consider how traditional techniques might be (mis-)applied in designing a microprocessor system: the designer could add a latch, encoder, and resistors for each digit of the display. Still another latch and decoder could be used to turn on one of the decimal points (if used). The characters displayed could only be a sequence of decimal digits. In the same vein, a large matrix of key switches could be read by installing an MSI TTL priority encoder read by an additional input port. Not only would all this use a lot of extra I/O ports and increase the system price and part count drastically, but the flexibility and reliability of the system would be greatly reduced.

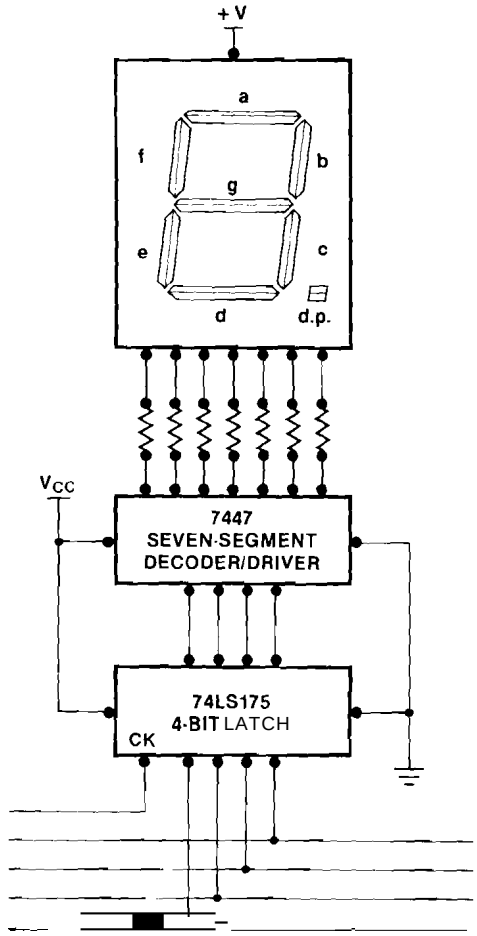

Figure 1. Wrong Way to Design Multiple Digit Displays for Microcomputer Systems

Instead, a scheme of time-multiplexing the display can be used to decrease costs, part count, and interconnections, while allowing a wider range of character types to be used on the display. The techniques used here are fairly typical of today's integrated subsystems designed especially for controlling keyboards and displays (such as in calculators or the Intel® 4269, 8278, and 8279 Keyboard/Display Controller Devices).

In a multiplexed display, all the segments of all the charecters are interconnected in a regular two-dimensional array. One terminal of each segment is in common with the other segments of the same character; the other terminal is connected with the same segments of the other characters. This is represented schematically in Figure 2. A digit driver or segment driver is needed for each of these common lines.

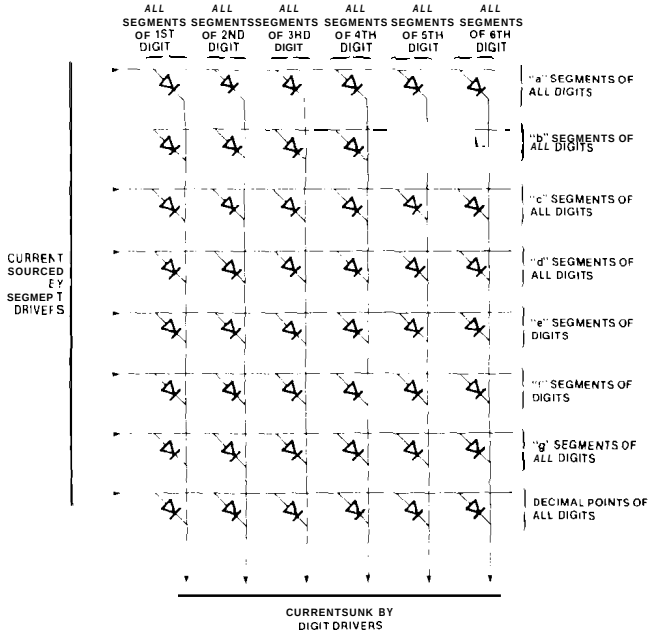

Figure 2. Schematic Representalion of 6-Digit, 7-Segment Common-Cathod LED Multiplexed Display

The various characters of the display are not all on at once; rather, only one character at a time is energized. As each character is enabled, some combination of segment drivers is turned on, with the result that a digit appears on the enabled character. (For example, in Figure 3, if segment drivers 'a', 'b', and 'c' were on when character position #6 was enabled, the digit '7' would appear in the left-most place.) Each character is enabled in this way, in sequence, at a rate fast enough to ensure that the display characters seem to be on constantly, w th no appearance of flashing or flickering.

In the system presented here, these rapid modifications tc the display are all made under the control of the MCS-48™ microcomputer. At periodic intervals the computer quickly turns off all display segments, disables the character now being displayed and enables the next, looks up the pattern of segments for the next character to be displayed, and turns on the appropriate segments. With the next character now turned on, the processor may now resume whatever it had been doing before. The whole display updating task consumes only a small fraction of the processor's time.

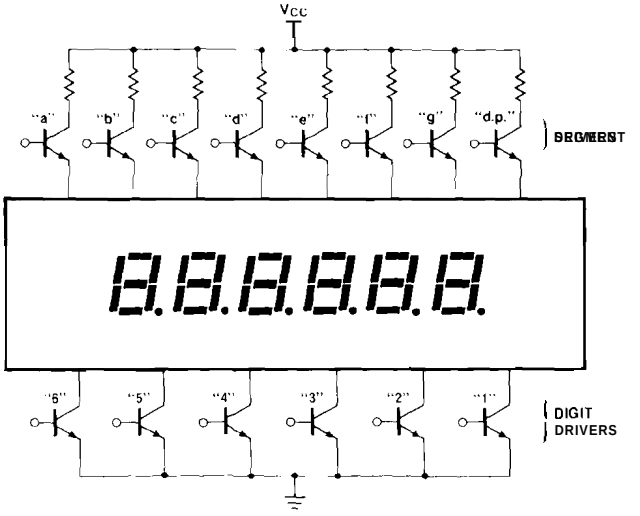

Figure 3. Segment and Digit Drivers used with 6-Position, 7-Segment LED Display

Moreover, since the computer rather than a standard decoder circuit is used to turn the segments off and on, patterns for characters other than decimal digits may be included in the display. Hexadecimal characters, special symbols, and many letters of the alphabet are possible. With sufficient imagination this feature can be exploited for some applications, as suggested by the examples in Figure 4.

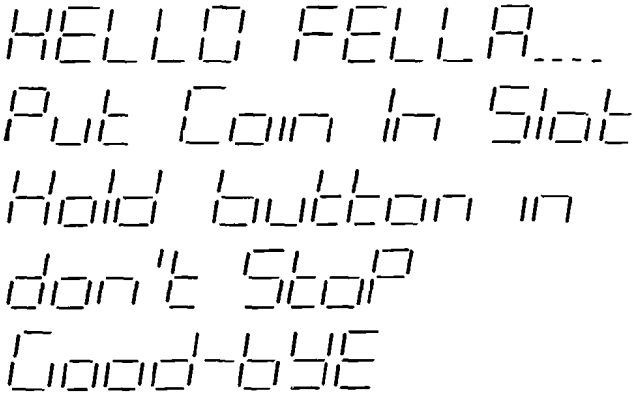

Figure 4. Examples of Typical Messages Possible with Simple 7-Segment Displays

As each character of the display is turned on, the same signal may be used to enable one row of the key matrix. Any keys in that row which are being pressed at the time will then pass the signal on to one of several "return lines", one corresponding to each column of the matrix. (See Figure *5.)* By reading the state of these control lines, and knowing which row is enabled, it is possible to compute which (if any) of the keys are down. Note that the keys need not be physically arranged in a rectangular array; Figure 5 is merely a schematic.

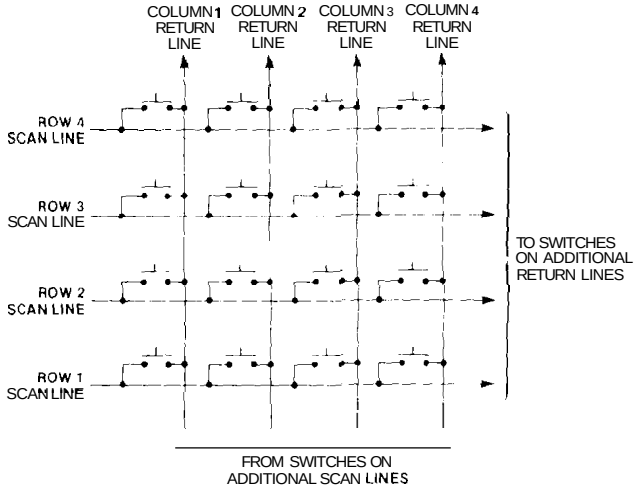

Figure 5. Schematic of X-Y Matrix Multiplexed Keyboard

Since each character is on for only a small fraction of the total display cycle, its segments must be driven with a proportionately higher current so that their brightness averages out over time. This requires character and segment drivers which can handle higher than normal levels of current. Various types of drivers can be used, ranging from specially designed circuits to integrated or discrete transistor arrays. The selection depends on several factors, including the type of display being used (LED, vacuum flourescent, neon, etc.), its size, the number of characters, and the polarity of the individual segments. Some drivers have active high inputs, some active low. Some invert their input logic levels, some do not. Some require insignificant input currents, some present a considerable load. Some systems use external logic to enable one of N characters or to produce the appropriate segment pattern for a given digit, some systems implement these functions through software.

Because of these and the other variables which make each application unique, provisions are made in the first page of symbol EQUates to allow the user to specify such things as the number of characters in the display or the polarity of the drivers used, and the program will be assembled accordingly. The display is refreshed on each timer interrupt, which occurs every 32 x (TICK) machine cycles. (One machine cycle occurs every 30 crystal oscillations for the 8021 and 8022, or every 15 oscillations for all other members of the family.) A more detailed explanation of these variables is included in the listing.

Port assignment is also at the discretion of the user — all port references in the listing are "logical" rather than physical port names. The port used to specify which character is enabled is referred to as "PDIGIT". The output segment pattern is written to "PSGMNT" and the keyboard return lines are read by "PINPUT". These logical port names may be assigned to whichever ports the user pleases.

By way of example, the breadboard used to develop snd debug this software used a matrix of 16 single-pole pushbuttons and an 8-character common-cathode LED display with right-hand decimal point. No decoders external to the 8748 microcomputer were used; all logic was handled through software. PDIGIT was the 8-bit bus, PSGMNT was port 1, and PINPUT was port 2. The drivers used were 75491 and 75492 logically noninverting buffers: high level inputs were used to turn a segment or character on. Pull-up resistors were used on the 8748 output lines to source the current levels needed by the buffers. The 8748 was socketed on the breadboard, and was driven with an inexpensive 3.59 MHz television crystal. The short test program included in this listing was used to echo key depressions as they were detected, and to invoke four demonstration subroutines. A summary of the subroutines included in this listing with a short explanation of the function of each is included in Figure 6; Figure 7 shows how the various utilities interact.

KBDIN	Keyboard Input. Waits until one keystroke input has been received from the keyboard; determines the meaning or legend of that key, and returns with the encoded value in the accumulator,
CLEAR	Blank out the display.
ENCACC	Encode accumulator with bit pattern corresponding to the segment pattern needed by the display to represent that symbol or character. Uses the value of the accumulator when called to access a table containing the patterns for all legal input values.
WDISP	**Write into Display.** Writes the bit pattern in the accumulator into the next character position of the display. Maintains a character position counter so that repeated calls will automatically write characters into sequential positions.
RENTRY	**Right-hand Entry.** Stores the accumulator segment pattern in the display in the right-most character position. Shifts all other characters to the left one place.
PRINT	Print a string of arbitrary characlers onto the display Useful lor prompting messages, warnings, etc. Uses a table of segment patterns in ROM, so that messages will not be restricted to numbers, letters, etc
FILL	Fill the display with the character pattern in the accumulator. Useful lor writing dashes, segment test patterns, etc. into all character positions.
ECHO	Walt for a key to be pressed by the operator and write that key onto the display. Used for providing feedback to the operator when entering numeric data etc.
RDPADD	Adds or deletes a decimal point to the character at the right-hand side of the display, for entering floating point numbers.
HOLD	Called when a key is known to be down. Does not return until all keys have been released. Used for organ-type keyboards, or when some action should not be initiated until the key invoking that action has been released.
DELAY	Provides a crude real time delay corresponding to the value of the accumulator when called Can be used to cause display characters to blink. to momentarily flash information, to enable a buzzer, etc. Could also be used by the program when delays are needed, such as to stow down the computer reaction rate while playing a game against the human operator

Figure 6. Utility Subroutine Delinitions

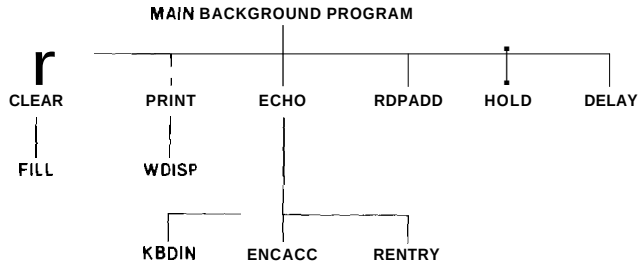

Figure 7. Subroutine interrelationships

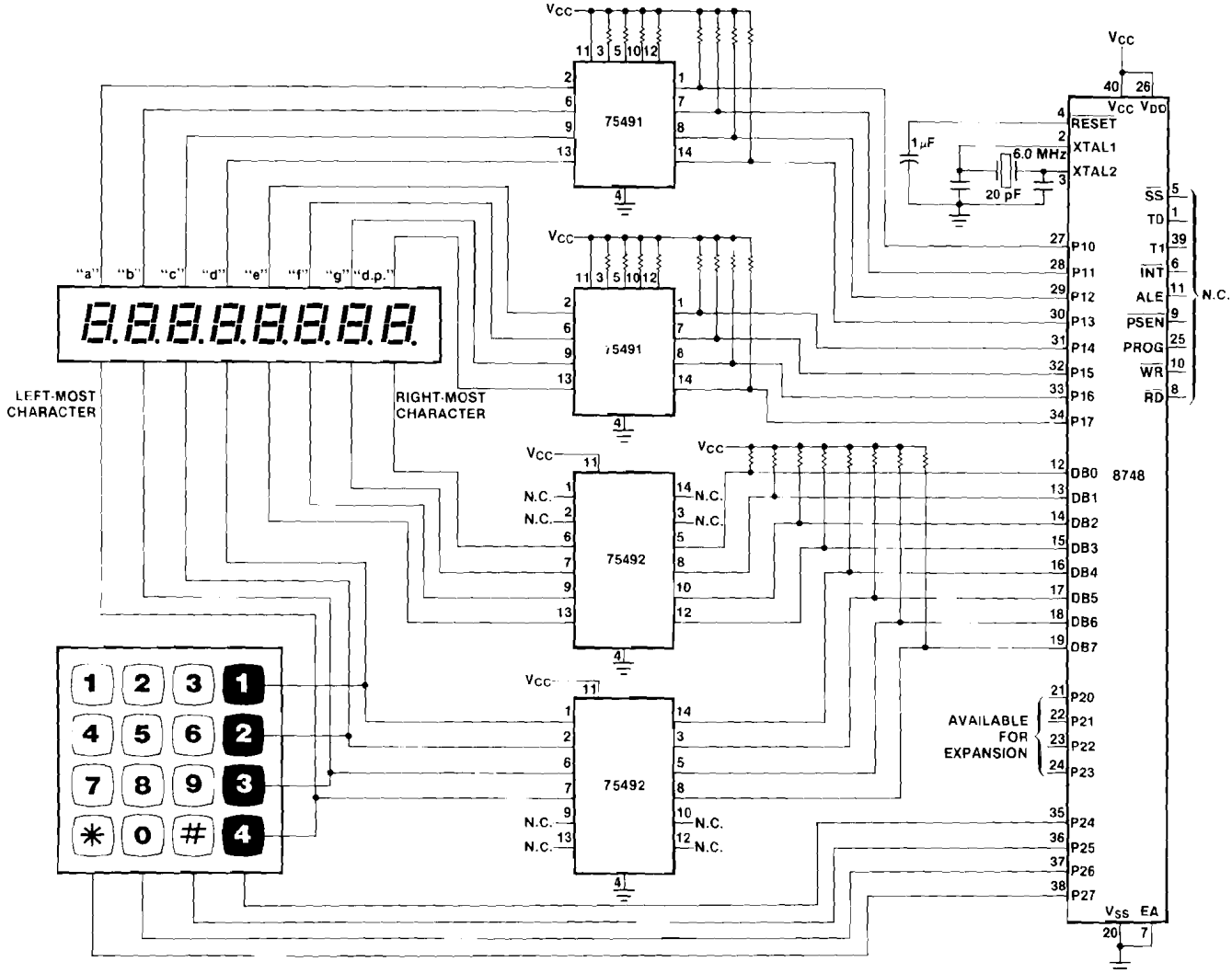

Figure 8 Prototype System Schematic

```
LOC  OBJ          SEQ          SOURCE STATEMENT

                     1 $MACROFILE XREF
                     2 $TITLE('AP40: INTEL MCS-48 KEYBOARD/DISPLAY APPLICATION NOTE APPENDIX')
                     3 ;
                     4 ;THE FOLLOWING SOFTWARE PACKAGE PROVIDES A SEVEN SEGMENT DISPLAY
                     5 ;INTERFACE FOR MICROCOMPUTERS IN THE INTEL MCS-48 FAMILY.
                     6 ;THE CODE IS WRITTEN SO THAT VARIOUS HARDWARE
                     7 ;CONFIGURATIONS CAN BE ACCOMODATED BY REDEFINING THE INITIAL VARIABLES.
                     8 ,IN MOST SITUATIONS, THE KEYBOARD/DISPLAY INTERFACE MILL BE REQUIRED TO
                     9 ;IMPLEMENT MORE SOPHISTICATED SINGLE-CHIP SYSTEMS (CALCULATORS,SCALES,CLOCKS.
                    10 ;ETC.), UITH SECTIONS OF THE FOLLOWING CODE SELECTEG AND MODIFIED AS NECESSARY
                    11 ;FOR EACH APPLICATION.
                    12 ;
                    13 ;A SINGLE SUBROUTINE (CALLED REFRSH) IS USED TO IMPLEMENT BOTH THE DISPLW
                    14 ;MULTIPLEXING AND KEYBOARD SCANNING, USING THE SAME SIGNAL BUTH TO ENABLE
                    15 ;ONE CHARACTER OF THE DISPLAY AND TO STROBE ONE ROW OF THE X-Y KEY MATRIX.
                    16 ;THE SUBROUTINE MUST BE CALLED SUFFICIENTLY OFTEN TO ENSURE THE DISPLAY
                    17 ;CHARACTERS DO NOT FLICKER- AT LEAST 50 COMPLETE DISPLAY SCANS PER SECOND.
                    18 ;TO ACCOMODATE SWITCHES OF ARBITRARY CHEAPNESS, THE DEBOUNCE TIME CAN BE
                    19 ;SET TO BE ANY DESIRED NUMBER OF COMPLETE SCANS.
                    26 ;THUS THE DEBOUNCE TIME IS A FUNCTION OF BOTH THE SCAN RATE AND THE VALUE
                    21 ;OF CONSTANT 'DEBNCE'.
                    22 ,
                    23 ;IN THIS LISTING, THE INTERNAL TIMER IS USED TO GENERATE INTERRUPTS THAT
                    24 ;SERVE AS A TIME BASE FOR THE REFRESH SUBROUTINE.
                    25 ;ALTERNATE TIME BASES MIGHT BE AN EXTERNAL OSCILLATOR (DRIVING THE INTERRUPT
                    26 ;PIN OR POLLED BY A TEST OR INPUT PIN), A SOFTWARE DELAY LOOP IN THE BACKGROUND
                    27 ,PROGRAM, OR PERIODIC CALLS TO THE SUBROUTINE FROM THROUGHOUT THE USER'S PROGRAM
                    28 ,AT APPROPRIATE PLACES.
                    29 .IN THESE CASES, THE CODE STARTING AT LABEL TIINT (TIMER INTERRUPT) AND TIRET
                    38 ;(TIINT RETURN) COULD STILL BE USED TO SAVE AND RESTORE ACCUMULATOR CONTENTS.
                    31 ;THE INTEFRUFT SERVICING ROUTINE SELECTS REGISTER BANK 1
                    12 ;FOR THE NEEDED REGISTERS.
                    33 ;
                    34 ;
                    35 ;WRITTEN BY JOHN WHARTON, INTEL SINGLE-CHIP COMPUTER APPLICATIONS
                    36 ;
                    37 $EJECT
```

```
LOC  OBJ          SEQ          SOURCE STATEKNT

                    38 ;IN THIS IMPLEMENTATION OF THE DISPLAY SCAN) IT IS ASSUMED THAT THERE WILL
                    39 ;BE RELATIVELY LITTLE I/O OTHER THAN FOR THE KEYBOARD/DISPLAY.
                    40 ;IF THIS IS THE CASE, THEN THERE IS NO NEED FOR FOR ANY ADDITIONAL EXTERNAL
                    41 ;LOGIC (SUCH AS ONE+-EIGHT   DECOMRS OR SEVEN-SEGMENT ENCODERS), THOUGH
                    42 ;THERE WILL STILL BE A NEED FOR CURRENT OR YOLTAGE DRIVERS, ACCORDING TO
                    43 ;THE TYPE OF DISPLAY BEING USED.
                    44 ;
                    45 ;IN THIS LISTING, THE PROCESSOR I/O PORTS ARE LOGICALLY DIVIDED A5 FOLLOWS:
                    46 ;
                    47 ;PDIGIT-EIGHT BIT PORT USED TO ENABLE. ONE AT A TINE,  THE INDIVIDUAL
                    48 ;       CHARACTERS OF AN EIGHT DIGIT SEVEN-SEGMENT DISPLAY, WHILE ALSO
                    49 ;       STROBING THE ROWS OF AN X-'i MATRIX KEYBOARD
                    50 ;       BIT? ENABLES THE LEFTMOST CHARACTER AND THE BOTTOM ROW OF THE KBD,
                    51 ;       BIT4 ENABLES THE TOP ROW OF THE 4X4 KBD AND THE FOURTH CHARACTER,
                    52 ;       BIT0 ENABLES THE RIGHTMOST CHARACTER.
                    53 ;       (A 4X8 KEYBOARD COULD BE STROBED BY ALSO USING BIT3-BIT0
                    54 ;       AND EXTENDING OR ELIMINATING THE TABLE, "LEGNDS".)
                    55 ;       THE ENABLING OF ONE BIT (ACTIVE HIGH OR LOW) IS ACCOMODATED BY
                    56 ;       ACCESSING A LO@#-UP TABLE CHLLED CHRSTB
                    57 ;       THIS TECHNIQUE TAKES ABOUT FOUR BYTES MORE ROM THAN A TECHNIQUE
                    58 ;       OF ROTATING A 'ONE'  THROUGH A FIELD OF 'ZEROES'  IN THE ACC
                    59 ;       AN APPROPRIATE NUMBER OF TIMES, BUT IT ALLOWS SOME ADDITIONAL
                    60 ;       FLEXABILITY: IF THE DRIVERS BEING USED WVE A COMBINATORIAL INPUT
                    61 ;       (AS IN THE 754% FWILY OF HIGH-CURRENT, HIM-VOLTAGE DRIVERS),
                    62 ;       THE CHKSTB TABLE COULD PROVIDE ENCODED OUTPUTS.  NINE DIGITS) FOR
                    63 ;       EXAMPLE, COULD BE ENABLED WITH SIX BITS OF (BUFFERED? OUTPUT:
                    64 ;       (001001,001010,001100,010001,010010,010100,100001,100010,100100)
                    65 ;       IF I/O LINES NEED TO BE CONSERVED, OR IF MANY DIGITS
                    66 ;       MUST BE DISPLAYED, AN EXTERNAL DECOVER COULD BE ADDED TO THE SYSTEM
                    67 ;       DURING CHARACTER TRANSITIONS A 'BLANK' CHARACTER IS
                    68 ;       EXPLICITLY WRITTEN TO THE DISPLAY.  THUS,
                    64 ;       THERE MILL BE NO CHARACTER 'SHADOWING' CAUSED BY THC.
                    70 ;       FACT THAT THE HARDWARE OR SOFTWARE DECODER KEEPS ONE
                    71 ;       OUTPUT, AND THUS ONE CHARACTER, ACTIVE AT FILL TIMES.
                    72 ;
                    73 ;PSGMNT-EIGHT BIT PORT TO ENABLE THE SEVEN SEGMENTS & D.P. OF A STANDARD
                    74 ;       DISPLAY.
                    75 ;       BIT7-BIT0 CORRESPOND TO THE DP AND SEGMENTS G THRWGH A, RESPECTIVELY
                    76 ;       IT IS POSSIBLE TO ACCOMODATE
                    77 ;       DRIVERS WHICH ARE EITHER LOGICALLY INVERTING OR NON-INVERTING BY
                    78 :       SETTING VARIABLE 'SEGPOL' (SEGMENT POLARITY).
                    79 ;       NOTE THRT BY HAVING ARBITRARY CONTROL OVER EACH SEGMENT, NON-NUMERIC
                    88 ;       CHARACTERS CAN BE REPRESENTED ON A SEVEN SEGMENT DISPLAY,
                    81 ;       AS SHOWN IN EXAMPLE SUBROUTINE 'TEST2'.
                    82 ;
                    83 $EJECT
```

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0
AP40: INTEL MCS-48 KEYBOARD/DISPLAY APPLICATION NOTE APPENDIX

 LOC  OBJ          SEQ          SOURCE STATEMENT

                     84 ;PINPUT-FOUR HIGH-ORDER BITS USED A5 INPUTS FROM THE KEYBOARD RETURN LINES.
                     85 ;       ASSUMES THAT A KEY DOWN IN THE CURRENTLY ENABLED ROW WOULD RETURN
                     86 ;       A LOW LEVEL.
                     87 ;       IN THIS CASE, BIT7 RETURNS THE LEFTMOST COLUMN, BIT4 THE RIGHTMOST.
                     88 ;       THE HIGH-ORDER BITS ARE USED SO THAT IF AN OFF-CHIP DECODER IS USED
                     89 ;       TO ENABLE UP TO 16 CHARACTERS, FOR EXAMPLE, IT COULD BE DRIVEN BY
                     90 ;       THE LOW ORDER BITS OF THE SAME PORT.
                     91 ;       NOTE ALSO THAT IF A SIXTEEN KEY MATRIX WERE ELECTRICALLY ORGANIZED
                     92 ;       IN A 2X8 ARRAY, ONLY TWO RETURN LINES WOULD BE NEEDED.
                     93 ;       (IN THIS CASE, PERHAPS T0 AND T1 COULD BE USED FOR INPUT BITS. )
                     94 ;
                     95 ;PULL-UP RESISTORS ON THE RETURN LINES NIGHT BE IN ORDER IF THERE IS ANY
                     96 ;POSSIBILITY OF A HIGH-IMPEDENCE CONDUCTIVE PATH THROUGH THE SWITCH WHEN
                     97 ;IT IS SUPPOSED TO BE 'OPEN".
                     98 ;(THIS PHENOMENON HAS ACTUALLY BEEN OBSERVED. )
                     99 ;
                    109 ;THE DRIVERS USED IN THE PROTOTYPE WERE K L NON-INVERTING IN THAT
                    101 ;A HIGH LEVEL ON AN OUTPUT LINE IS USED TO TURN A CHARACTER OR SEGMENT ON.
                    182 ;THERE ARE A TOTAL OF SEVEN I/0 LINES LEFT OVER.
                    103 ;
                    184 ;THE ALGORITHM FOR DRIVING THE DISPLAY USES A BLOCK OF INTERNAL RAM
                    185 ;AS DISPLAY REGISTERS, WITH ONE BYTE CORRESPONDING TO EACH CHARACTER OF THE
                    186 ;DISPLAY.  THE EIGHT BITS OF EACH BYTE CORRESPOND TO THE SEVEN SEGMENTS & DP
                    107 ;OF EACH CHARACTER.  IF AN EX1ERNAL ENCODER IS USED (SUCH AS A FOUR-BIT TO
                    108 ;SEVEN-SEGMENT ENCODER OR A ROM FOR TRANSLATING ASCII TO
                    109 ;SIXTEEN-SEGMENT "STARBURST" DISPLAY PATTERNS), THE TABLE ENTRIES WOULD HOLD
                    110 ;THE CHARACTER CODES. (IN THE FORMER CASE, AN IJNUSED BIT COULD BE USED TO
                    111 ;ENABLE THE D.P. )
                    112 ;THUS, WRITING CHARACTERS TO THE DISPLAY FROM THE BACKGROUND PROGRAM
                    113 ;REALLY ENTAILS WRITING THE APPROPRIATE SEGMENT
                    114 ;PATTERNS TO A DISPLAY REGISTER- THE ACTUAL OUTPUTTING IS AUTOMATIC.
                    115 ;THE LEFTMOST CHARACTER CORRESPONDS TO THE LAST BYTE OF THE DISPLAY
                    116 ;REGISTERS,  AND IS ACCESSED BY NEXTPL=8 (SEE SOURCE); THE RIGHTMOST
                    117 ;CHARACTER IS THE FIRST DISPLAY BYTE,  WHEN NEXTPL=1.
                    118 ;UTILITY SUBROUTINES ARE INCLUDED HERE TO TRANSLATE FOUR BIT NUMBERS TO HEX
                    119 ;DIGIT PATTERNS:  AND WRITE THEM INTI? THE DISPLAY REGISTERS SEQUENTIALLY
                    129 ;(EITHER FILLING FROM THE LEFT- H.P.  CALCULATOR STYLE OR FROM THE
                    121 ;RIGHT- T.I. STYLE;  SUBROUTINES WDISP AND RENTRY, RESPECTIVELY!.
                    122 ;
                    123 ;THE KEYBOARD SCANNING ALGORITHM SHOWN HERE REQUIRES A KEY BE DOWN FOR
                    124 ;SOME NUMBER OF COMPLETE DISPLAY SCANS TO BE ACKNOWLEGED.  SINCE IT IS
                    125 ;INTENDED FOR 'ONE-FINGER' OPERATION, TWO-KEY ROLLOVER/N-KEY LOCKOUT HAS
                    126 ;BEEN IMPLEMENTED.  HOWEVER, MODIFICATIONS WOULD BE POSSIBLE TO ALLOW, FOR
                    127 ;EXAMPLE, ONE KEY IN THE MATRIX TO BE USED HS A SHIFT KEY OR CONTROL KEY
                    128 ;TO BE HELD DOWN WHILE ANOTHER KEY IN THE MATRIX IS PRESSED.  (SEE NOTE WITHIN
                    129 ;THE BODY OF THE LISTING. )
                    130 ;
                    131 $EJECT
```

```
LOC  OBJ          SEQ          SOURCE STATEMENT

                   132 ;(BE AWARE THAT NO MORE THAN TWO KEYS CAN EVER BE DOWN UNLESS DIODES
                   133 ;ARE PLACED IN SERIES WITH ALL OF THE SWITCHES- CERTAINLY NOT THE CASE FOR EL
                   134 ;CHEAPO KEYBOARDS- BECAUSE SOME COMBINATIONS OF THREE KEYS DOWN WILL RESULT
                   135 ;IN A 'PHANTOM' FOURTH KEY BEING PERCEIVED.
                   136 ;THE PHANTOM KEY WOULD BE THE FOURTH 'CORNER' WHEN THREE KEYS FORMING
                   137 ;A RECTANGULAR PATTERN (IN THE X-Y KEY MATRIX) ARE DOWN.?
                   138 ;IF DIODES ARE PLACED IN THE SCANNING ARRAY, CONSIDERATIONS MUST BE MADE
                   139 ;ABOUT HOW THE DIODE VOLTAGE DROP WILL AFFECT INPUT LOGIC LEVELS.
                   148 ;
                   141 ;WHEN A DEBOUNCED KEY IS DETECTED, THE NUMBER OF ITS POSITION IN THE KEY
                   142 ;MATRIX (LEFT-TO-RIGHT, BOTTOM-TO-TOP, STARTING FROM 00) IS PLKED INTO
                   143 ;RAM LOCATION 'KBDBUF'. AN INPUT SUBROUTINE THEN NEED ONLY READ THIS LOCATION
                   144 ;REPEATEDLY TO DETERMINE WHEN A KEY HAS BEEN PRESSED. WEN h KEY IS DETECTED,
                   145 ;A SPECIAL CODE BYTE SHOULD GE WRITTEN BACK TO INTO 'KBDBW' TO PREVENT
                   146 ;REPEATED DETECTIONS OF THE SAME KEY.
                   147 ;THE ROUTINE 'KBDIN' DEMONSTRATES A TYPICAL INPUT PROTOCOL, ALONG WITH A METHOD
                   148 ;FOR TRANSLATING A KEY POSITION TO ITS ASSOCIATED SIGNIFICANCE BY ACCESSING
                   149 ;TABLE 'LEGNDS' IN ROM.
                   150 ;
                   151 $EJECT
```

```
LOC  OBJ        SEQ        SOURCE STATEMENT

                152 ;*********************************************************
                153 ;
                154 ;       INITIAL EQUATES TO DEFINE SYSTEM CONFIGURATION
                155 ;
                156 ;*********************************************************
                157 ;
0010            158 PDIGIT  EQU     BUS     ;USED TO ENABLE CHARACTERS AND STROBE ROWS OF KEYBOARD
0008            159 PSGMNT  EQU     P1      ;USED TO TURN ON SEGMENTS OF CURRENTLY ENABLED DIGIT
0009            160 PINPUT  EQU     P2      ;PORT USED TO SCAN FOR KEY CLOSURES
                161                         ;(NOTE THAT THIS PORT ALLOCATION USES THE HIGHER
                162                         ;CURRENT SOURCING ABILITY OF THE BUS TO SWITCH ON THE
                163                         ;DIGIT DRIVERS, AND LERVES P23-P20 FREE FOR USING
                164                         ;AN 8243 PORT EXPANDER IN THE SYSTEM.)
                165 ;
0000            166 POSLOG  EQU     00H
00FF            167 NEGLOG  EQU     0FFH
                168 ;
0000            169 CHRPOL  EQU     POSLOG  ;DEFINES  WHETHER OUTPUT LINES ARE ACTIVE HI OR LOW
0000            170 SEGPOL  EQU     POSLOG  ;FOR DRIVING CHARACTERS AND SEGMENT PATTERNS
00F0            171 INPMSK  EQU     0F0H    ;DEFINES BITS USED AS INPUT
                172 ;
0008            173 CHARNO  EQU     8       ;NUMBER OF DIGITS IN DISPLAY
0004            174 NROWS   EQU     4       ;ROWS OF KEYS (LESS THAN OR EQUAL TO CHARNO)
0004            175 NCOLS   EQU     4       ;LESSER DIMENSION OF KEYBOARD MATRIX
                176 ;
FFF0            177 TICK    EQU     -10H    ;DETERMINES INTERRUPT INTERVAL
0004            178 DEBNCE  EQU     4       ;NUMBER OF SUCESSIVE SCANS BEFORE KEY CLOSURE ACCEPTED
0000            179 BLANK   EQU     00H     ;CODE TO BLANK DISPLAY CHARACTERS.
                180                         ;(WOULD BE 20H IF ASCII DECODING ROM USED OR 0FH IF
                181                         ;7447-TYPE SEVEN-SEGMENT DECODER EXTERNAL TO 8748)
                182 ;
000F            183 ENCMSK  EQU     0FH     ;KLECTS WHICH BITS ARE RELEVANT TO ENCACC SUBROUTINE
                184 ;
                185 $EJECT
```

```
LOC  OBJ        SEQ        SOURCE STATEMENT

                186 ;*************************************************************
                187 ;
                188 ;       BANK 0 REGISTERS USED
                189 ;
                190 ;POINTERS USED FOR INDIRECT RAM ACCESSING:
0000            191 PNTR0   EQU     R0
0001            192 PNTR1   EQU     R1
0007            193 NEXTPL  EQU     R7      ;USED TO KEEP TRACK OF CHARACTER POSITION BEING
                194                         ;WRITTEN INTO
                195 ;
                196 ;*************************************************************
                197 ;
                198 ;       BANK 1 REGISTER ALLUCRTIUN
                199 ;
                200 ;PNTR0  EQU     R0      (ALREADY DEFINED)
                291 ;PNTR1  EQU     R1
0002            202 ASAVE   EQU     R2      ;HOLDS ACCUMULATOR VALUE DURING SERVICE ROUTINE
0004            283 ROTPAT  EQU     R4      ;USED TO HOLD INPUT PATTERN BEING ROTATED THROUGH CY
0005            284 RUTCNT  EQU     R5      ;COUNTS NUMBER OF BITS ROTATED THROUGH CY
0006            205 LASTKY  EQU     R6      ;HOLDS KEY POSITION OF LRST KEY DEPRESSION DETECTED
0007            206 CURDIG  EQU     R7      ;HOLDS POSITION OF NEXT CHARACTER TO BE DISPLAYED
                287 ;
                208 ;*************************************************************
                289 ;
                218 ;       DATA RRH ALLOCATION
                211 ;
0020            212 NREPTS  EQU     32      ;KEEPS TRACK OF SUCCESSIVE READS OF SAME KEYSTROKE
0021            213 KEYLOC  EQU     33      ;INCREMENTED AS SUCCESSIVE KEY LOCATIONS SCANNED
0022            214 KBDBUF  EQU     34      ;CARRIES POSITION OF DEBOUNCED KEY FROM REFRSH ROUTINE
                215                         ;\ BACK TO BACKGROUND PROGRAM
0023            216 RMLRY   EQU     35      ;NON-ZERO WHEN DISPLAY IN PROGRESS
                217 ;
                218 ;       THE LAST <CHARNO> REGISTERS HOLD THE DISPLAY SEGMENT PATTERNS
                219 ;
0037            228 S E W   EQU     (63-CHARNO)     ;BASE OF REGISTER ARRAY FOR DISPLAY PATTERNS
                221                                 ;\ (COULD BE ANYWHERE IN INTERNAL RAM)
                222 ;
                223 ;*************************************************************
                224 ;
                225 ;       NOTE THAT LASTKY, CURDIG, AND F1 RETAIN STATUS INFORMATION FROM
                226 ;       ONE INTERRUPT TO THE NEXT.  ALL OTHER REGISTERS MAY BE USED IN
                227 ;       THE UKR'S OWN INTERRUPT SERVICING ROUTINE
                228 ;
                229 ;*************************************************************
                239 ;
                231 $EJECT
```

```
LOC  OBJ        SEQ        SOURCE STATEMENT

                232 ;
                233 ;*************************************************************
                234 ;
0000            235 ORG     000H
0000 0460       236         JMP     INIT
                237 ;
                238 ;
                239 ;*************************************************************
                240 ;
0007            241 ORG     007H
                242 ;
                243 ;TIINT  TIMER INTERRUPT SUBROUTINE.
                244 ;       CALL MADE TO LOC 007H WHEN TIMER TIMES OUT.
                245 ;       TIMER CHN BE RE-INITIALLIZED AT THIS POINT IF DESIRED.
                246 ;       USED HERE TO CAUSE THE DISPLAY REFRESH AND KEY SCAN ROUTINES TO
                247 ,       BE CALLED PERIODICALLY.
0007 D5         248 TIINT:  SEL     RB1
0008 AA         249         MOV     ASAVE,A
0009 23F0       250         MOV     A,#TICK
000B 62         251         MOV     T,A             ;RELOAD TIMER INTERVAL
                252 ;
                253 ;*************************************************************
                254 ;
                255 ;       THE USER'S OWN TIMER INTERRUPT ROUTINE (IF IT EXISTS? COULD
                256 ;       BE PLACED AT THIS POINT
                257 ;
                258 ;*************************************************************
                259 ;
000C 1410       260         CALL    REFRSH          ;CRUSE DISPLAY TO EE UPDATED
                261 ;
                262 ;       THE COMPLETE INTERRUPT ROUTINE SHOULD BE COPIED HERE
                263 ;       TO SRVE A FULL LEVEL OF SUBROUTINE NESTING.
                264 ;       IT WAS NRITTEN AS A SUBROUTINE HERE FOR THE SAKE OF CLARITY.
                265 ;
                266 ;*************************************************************
                267 ;
                268 ;TIRET  TIMER INTERRUPT RETURN CODE- RESTORES ACC VALUE
000E FA         269 TIRET:  MOV     A,HSRVE
000F 93         270         KETR
                271 ;
                272 SEJECT
```

```
LOC  OBJ        SEQ        SOURCE STATEMENT

                273 ;*********************************************************
                274 ;REFRSH SUBROUTINE TO MULTIPLEX SEVEN-SEGMENT DISPLAYS.
                275 ;       EACH CALL CAUSES THE NEXT CHARACTER TO BE DISPLAYED,
                276 ;       ACCORDING TO THE CONTENTS OF THE SEGMAP REGISTER ARRAY
                277 ;       REFRSH SHOULD BE CALLED fi7 LEAST EVERY MSEC OR SO.
                278 ;*********************************************************
                279 ;
0010 2300       280 REFRSH: MOV     A,#BLANK XOR SEGPOL
0012 39         281         OUTL    PSGMNT,A        ;WRITE BLANK PATTERN TO SEG DRIVERS
0013 2357       282 REFR1:  MOV     A #CHRSTB       ;LOOK UP DIGIT ENABLE PATTERN
0015 6F         283         ADD     A,CURDIG        ;ADD CURDIG DISPLACEMENT
0016 A3         284         MOVP    A,@A            ;ENABLE ONE BIT OF ACCUMULATOR
0017 02         285         OUTL    PDIGIT,A        ;ENERGIZE CHARACTER
                286 ;
                287                                 ;WRITE NEXT SEGMENT PATTERN
0018 2337       288         MOV     A,#SEGMAP       ;LOAD BASE OF REGISTER ARRAY
001A 6F         289         ADD     A,CURDIG        ;ADD CURDIG DISPLACMENT
001B A9         290         MOV     PNTR1,A
001C F1         291         MOV     A @PNTR1        ;LOAD ACC W/ NEXT SEGMENT PATTERN
001D 39         232         OUTL    PSGMNT,A        ;ENABLE APPROPRIATE SEGMENTS
                293 ;
                294 ;*********************************************************
                295 ;       THE NEXT CHARACTER IS NOW BEING DISFLHYED.
                296 ;       THE KEYBOARD SCAN ROUTINE IS INTEGRATED INTO THE DISPLHY SCAN.
                297 ;       WITH THE CURRENT ROW ENERGIZED, CHECK IF THERE APE ANY INPUTS.
                298 ;*********************************************************
                293 ;
001E B821       300 SCAN:   MOV     PNTR0,#KEYLOC   ;SET POINTER FOR SEVERAL KEYLOC REFERENCES
0020 0A         301         IN      A,PINPUT        ;LOAD HNY SWITCH CLOSURES
                382 ;
                303 ;#########################################################################
                304 ;##     THIS BLOCK OF CODE IS NOT NEEDED BY THE KEYBOARD SCAN LOGIC     ###
                305 ;##     HOWEVER, ITS INCLUSION WOULD SPEED THINGS UP A BIT BY          ###
                306 ,##     SKIPPING OVER ROWS IN WHICH NO KEYS APE DOWN.                  ###
                397 ;##     IT WAS OMITTED HERE TO CONSERVE ROM SPACE, BUT MIGHT BE        ###
                398 ;##     RESTORED IF VERY LARGE KEYBOARDS (ESPECIALLY THOSE WITH EIGHT  ###
                309 ;##     KEYS PER ROW) ARE TO EE USED WITH THIS ALGORITHM.              ###
                310 ;#########################################################################
                311 ;##     CPL     A               ;ANY CLOSURES DETECTED ARE NOW ONE BITS ###
                312 ;##     ANL     A,#INPMSK                                              ###
                313 ;##     JNZ     SCAN1   ;-IF A KEY IN THE CURRENTLY ENABLED ROW IS DOWN ###
                314 ;##;    NO KEY IS NOW DOWN 50 THE KEYLOC COUNT MAY BE UPDATED DIRECTLY  ###
                315 ;##     MOV     A,@PNTR0                                               ###
                316 ;##     ADD     A,#NCOLS                                               ###
                317 ;##     MOV     @PNTR0,A                                               ###
                318 ;##     JMP     SCAN6                                                  ###
                319 ;#########################################################################
                320 ;##     IF THIS CODE IS USED, SUBSTITUTE THE 'JC  SCAN5' FOUR LINES     ###
                321 ;##     HENCE WITH 'JNC  SCAN5' TO ACCOMODATE THE INVERTED POLARITY     ###
                322 ;#########################################################################
                323 $EJECT
```

```
LOC  OBJ        SEQ        SWRCE STATEMENT

                324 ;*****************************************************
                325 ;       ROTATE BITS THROUGH THE CY WHILE INCREMENTING KEYLOC.
                326 ;*****************************************************
                327 ;
0021 BD04       328 SCAN1:  MOV     ROTCNT,#NCOLS   ;K T UP FOR <NCOLS> LOOPS THROUGH 'NXTLOC'
0023 F7         329 NXTLOC: RLC     A
0024 AC         330         MOV     ROTPAT,A        ;SAVE SHIFTED BIT PATTERN
0025 F63F       331         JC      SCAN5           ;ONE BIT IN CY INDICATES KEY NOT DOWN
                332 ;
                333 ;*************************************************************
                334 ;
                335 ;       AT THIS POINT IT HAS JUST BEEN DETERMINED THAT THE VALUE
                336 ;       OF KEYLOC IS THE POSITION OF A KEY WHICH IS NOW DOWN.
                337 ;       THE FOLLOWING CODE DEBOUNCES THE KEY, ETC.
                338 ;       IF MODIFICATIONS TO THE KEYBOARD LOGIC, I.E. THE INCLUSION
                339 ;       OF h SHIFT, CONTROL! OR MODE KEY IN THE KEY MATRIX ITSELF?
                340 ;       ARE DESIRED, THEY SHOULD BE MADE AT THIS POINT, BEFORE
                341 ;       THE DEBOUNCE LOGIC BEGINS.  FOR EXAMPLE, AT THIS POINT
                342 ;       KEYLOC COULD BE COMPARED AGAINST THE POSITION OF THE MODE
                343 ;       KEY:  AND IF THEY MATCH SET SOME FLAG BIT AND JUMP TO
                344 ;       LABEL 'SCAN5'.  OR, BY COMPARING KEYLOC AGAINST THE LAST
                345 ;       KEY DEBOUNCED, IMMEDIATE TWO-KEY ROLLOVER COULD BE
                346 ;       IMPLEMENTED.
                347 ;
                345 ;*****************************************St**************
                349 ;
0027 A5         350         CLR     F1              ;MARK THAT AT LEAST ONE KEY WAS DETECTED
0028 B5         351         CPL     F1              ;\ IN THE CURRENT SCAN
                352 ;
                353 ;*************************************************************
                354 ;       A KEYSTROKE WAS DETECTED FOR THE CURRENT COLUMN.  ITS
                355 ;       POSITION IS IN REGISTER KEYLOC.  SEE IF SAME KEY SENSED LAST CYCLE.
                356 ;*************************************************************
                357 ;
0029 F0         358         MOV     A,@PNTR0        ;PNTR0 STILL HOLDS #KEYLOC
002A 2E         359         XCH     A,LASTKY
002B DE         360         XRL     A,LASTKY
002C B820       361         MOV     PNTR0,#NREPTS   ;PREPARE TO CHECK AND/OR MODIFY REPEAT COUNT
002E C634       362         JZ      SCAN3
                363 ;
                364 $EJECT
```

```
LOC  OBJ        SEQ        SOURCE STATEMENT

                365 ;*************************************************************
                366 ;       A DIFFERENT KEY WAS READ ON THIS CYCLE THAN ON THE PREVIOUS CYCLE.
                367 ;       SET NREPTS TO THE DEBOUNCE PARAMETER FOR A NEW COUNTDOWN.
                368 ;*************************************************************
                369 ;
0030 B004       378         MOV     @PNTR0,#DEBNCE
0032 043F       371         JMP     SCAN5
                372 ;
                373 ;*************************************************************
                374 ;       SAME KEY WAS DETECTED AS ON PREVIOUS CYCLE
                375 ;       LOOK AT NREPTS: IF ALREADY ZERO, DO NOTHING.
                376 ;       ELSE DECREMENT NREPTS.
                377 ;       IF THIS RESULTS IN ZERO, MOVE LASTKY INTO KBDBUF.
                378 ;*************************************************************
                379 ;
0034 F0         380 SCAN3:  MOV     A,@PNTR0
0035 C63F       381         JZ      SCAN5           ;IF ALREADY ZERO
0037 07         352         DEC     A               ;INDICATE ONE MORE SUCCESIVE KEY DETECTION
0038 A0         383         MOV     @PNTR0,A
0039 963F       354         JNZ     SCAN5           ;IF DECREMENT DOES NOT RESULT IN ZERO
003B FE         385         MOV     A,LRSTKY
003C B822       386         MOV     PNTR0,#KBDBUF
003E A0         387         MOV     @PNTR0,A        ;TO MARK NEW KEY CLOSURE
                388 ;
003F B821       389 SCAN5:  MOV     PNTR0,#KEYLOC
0041 10         398         INC     @PNTR0
0042 FC         391         MOV     A,ROTPAT
0043 ED23       392         DJNZ    ROTCNT,NXTLOC
                393 ;
                394 ;
0045 EF57       395 SCAN6:  DJNZ    CURDIG,SCAN9
                396 ;
                397 $EJECT
```

```
LOC  OBJ        SEQ        SOURCE STATEKNT

                398 ;
                399 ;*********************************************************
                400 ;       THE FOLLOWING CODE SEGMENT IS USED BY THE KEYBOARD SCANNING ROUTINE.
                481 ;       IT IS EXECUTED ONLY AFTER A REFRESH SEQUENCE OF HLL
                402 ;       THE CWACTERS IN THE DISPLAY IS COMPLETED
                403 ;*********************************************************
                404 ;
0047 BF08       405         MOV     CURDIG,#CHARNO
0049 B000       406         MOV     @PNTR0,#0       ;PNTR0 STILL CUNTRINS #KEYLOC
004B 764F       407         JF1     SCAN8           ;JUMP IF ANY K E K WERE DETECTED
004D BEFF       408         MOV     LASTKY,#0FFH    ;CHANGE <LASTKY> WHEN NO KEYS ARE GOWN
004F A5         409 SCAN8:  CLR     F1
                410 ;
                411 ;*********************************************************
                412 ;       THE NEXT CODE SEGMENT IS THE INTERRUPT-DRIVEN PORTION OF THE 'DELAY'
                413 ;       UTILITY. IT DECREMENTS RAM LOCATION 'RDELRY' ONCE PER DISPLAY SCAN
                414 ;       IF 'RELAY' IS NOT ALREADY ZERO.
                415 ;*********************************************************
                416 ;
0050 B923       417         MOV     PNTR1,#RDELAY
0052 F1         415         MOV     A,@PNTR1
0053 C657       419         JZ      SCAN9
0055 07         428         DEC     A
0056 A1         421         MOV     @PNTR1,A
                422 ;
0057 83         423 SCAN?.  RET
                424 ;
                425 ;*********************************************************
                426 ;
                427 .CHRSTB IS THE BASE FOR THE PATTERNS TO ENWLE ONE-OF-CHARNO CHARACTERS.
0057            428 CHRSTB  EQU     ($-1) AND 0FFH
0058 01         429         DB      (00000001B XOR CHRPOL)
0059 02         430         DB      (00000010B XOR CHRPOL)
005A 04         431         DB      (00000100B XOR CHRPOL)
005B 08         432         DB      (00001000B XOR CHRPOL)
005C 10         433         DB      (00010000B XOR CHRPOL)
005D 20         434         DB      (00100000B XOR CHRPOL)
005E 40         435         DB      (01000000B XOR CHRPOL)
005F 80         436         DB      (10000000B XOR CHRPOL)
                437 .
                435 $EJECT
```

```
LOC  OBJ        SEQ         SOURCE STATEMENT

                439 ;INIT   INITIALIZES PROCESSOR REGISTERS
0060 D5         448 INIT:   SEL     RB1
0061 BF08       441         MOV     CURDIG,#CHARNO
0063 B822       442         MOV     PNTR0,#KBDBUF
0065 B0FF       443         MOV     @PNTR0,#0FFH
0067 B821       444         MOV     PNTR0,#KEYLOC
0069 B000       445         MOV     @PNTR0,#0
006B 23F0       446         MOV     A,#INPMSK
006D 3A         447         WTL     PINPUT,A        ;SET BIDIRECTIONAL INPUT LINES
006E C5         448         SEL     RB0
006F 149E       449         CALL    CLEAR           ;UTILITY FOR SETTING INITIAL DISPLAY REGISTERS.
0071 A5         458         CLR     F1
0072 23F0       451         MOV     A,XTICK         ;LOAD INTERRUPT RRTE VALUE
0074 62         452         MOV     T,A
0075 55         453         STRT    T
0076 25         454         EN      TCNTI           ;ENABLE TIMER INTERRUPTS
                455 ;
                456 ;
                457 ;*************************************************************
                458 ;
                459 ;ECHO   CHECK FOR ANY NEW KEYSTROKES DETECTED.
                460 ;       TRANSLATE EACH KEYSTROKE INTO A SEGMENT PATTERN
                461 ;       HND WRITE IT INTO THE APPROPRIATE DISPLAY REGISTER.
                462 ;
                463 ;*************************************************************
                464 ;
0077 1483       465 ECHO:   CALL    KBDIN           ;GET NEXT KEYSTRME
0079 B281       466         JB5     FKEY            ;JUMP IF KEY IN RIGHTHAND COLUMN
                467 ;       SINCE THE ACC IS USED BY ENCACC AND RENTRY, ITS CONTENTS MUST
                468 ;       BE PROCESSED OR SAVED BEFORE ENCACC IS CALLED
007B 14BA       469         CALL    ENCACC          ;FORM APPROPRIATE SEGMENT PATTERN
007D 14DB       470         CALL    RENTRY          ;WRITE PATTERN INTO DISPLHY REGIS1ERS
007F 0477       471         .       ECHO            ;LOOP INDEFINITELY
                472 ;
0081 2400       473 FKEY:   JMP     FUNCTN          ;JUMP TO OFF-PAGE CODE TO CRL DEW ROUTINE
                474 ;
                475 $EJECT
```

```
 LOC  OBJ        SEQ        SOURCE STATEMENT

                  476 ;*********************************************************
                  477 ;
                  478 ;       THE FOLLOWING SUBROUTINES IMPLEMENT THE UTILITIES COMMONLY USED FOR
                  479 ;       MOST KEYBOARD/DISPLAY APPLICATIONS.
                  480 ;       THEY COULD BE URD EXACTLY AS SHOWN HERE OR ADAPTED FOR SPECIAL CASES.
                  481 ;
                  482 ;*********************************************************
                  483 ;
                  484 ;KBDIN  KEYBOARD INPUT SUBROUTINE.
                  485 ;       COULD BE USED TO IHTERFRCE THE USER'S  BACKGROUND PROGRAM WITH
                  486 ;       THE INTERRUPT DRIVEN KEYBOARD SCANNER.
                  487 ;       RETURNS ONLY AFTER A NEW KEYSTROKE HAS BEEN DETECTED AND DEBOUNCED.
                  488 ;       ENCODED VALUE OF KEY (RATHER THAN ITS POSITION IN SWITCH MATRIX) IS
                  489 ;       RETURNED IN THE ACCUMULATOR.
0083 B922         490 KBDIN:  MOV     PNTR1,#KBDBUF
0085 2384         491         MOV     A,#80H          ;KBDBUF WILL BE HARKED AS CLEAR
0087 21           492         XCH     A,@PNTR1        ;LOAD BUFFER VALUE
8688 F283         493         JB7     KPDIN
008A 038E         494         ADD     A,#LEGNDS       ;ADD BASE OF KEY ENCODING TABLE
008C A3           495         MOVP    A,@A            ;OBTAIN BYTE REPRESENTING KEY SIGNIFICANCE
008D 83           496         RET
                  497 ;
                  498 ;
                  499 ;LEGNDS IS THE BASE FOR TABLE SHOWING KEY MATRIX SIGNIFICANCE
                  500 ;       FOR THE KEYBOARD USED IN THE PROTOTYPE.
                  561 ;       KEY LAYOUT IS AS SHOWN TO THE RIGHT.
                  502 ;
                  503 ;       NOTE THHT BIT6-BIT4 MAY BE USED TO ENCODE KEY TYPE.  IN THIS CASE:
                  504 ;               BIT4 INDICATES REGULAR DECIMAL DIGITS,
                  505 ;               PITS INDICATES RIGHT-COLUMN FUNCTION KEYS,
                  506 ;               BIT6 INDICRTES PUNCTUATION MARKS ( * AND # ).
                  507 ;
008E              508 LEGNDS  EQU     ($ AND 0FFH)    ;USE LOW ORDER BITS AS TABLE INDEX
008E 4F           509         DB      4FH
008F 10           510         DB      10H
0090 4E           511         DB      4EH
0091 28           512         DB      28H       PDIGIT4==>  1     2     3     <1>
0092 17           513         DB      17H
0093 18           514         DP      18H     ; PDIGIT5==>  4     5     6     <2>
0094 19           515         DB      13H
0095 24           516         DB      24H     ; PDIGIT6==>  7     8     9     <3>
0096 14           517         DB      14H
0097 15           518         DB      15H     ; PDIGIT7==>  *     0     #     <4>
0098 16           519         DB      16H
0099 22           520         DB      22H     ;             '     !     '      !
009A 11           521         DB      11H     ;             !     !     !      '
009B 12           522         DB      12H     ;             V     V     V      Q
009C 13           523         DB      13H     ;          PINPUT7 PINPUT6 PINPUT5  PINPUT4
009D 21           524         DB      21H
                  525 $EJECT
```

```
LOC  OBJ        SEQ        SOURCE STATEMENT

                526 ;*************************************************************
                527 ;
                528 ;CLEAR  WRITES 'BLANK' CHARACTERS INTO ALL DISPLAY REGISTERS.
                529 ;       RETURNS WITH NEXTPL SET TO LEFTMOST CHARACTER POSITION
                530 ;FILL   WRITES SEGMENT PFITTERN NOW IN ACC INTO ALL DISPLAY REGISTERS
009E 2300       531 CLEAR  MOV     A,#BLANK XOR SEGPOL
00A0 B938       532 FILL   MOV     PNTR1,#SEGMAP+1
00A2 BF08       533        MOV     NEXTPL,#CHARNO
00A4 A1         534 CLR1:  MOV     @PNTR1,A        ;STORE THE BLRNK CODE
00A5 19         535        INC     PNTR1           .;POINT TO NEXT CHARACTER TO THE LEFT
00A6 EFA4       536        DJNZ    NEXTPL,CLR1
00A8 BF08       537        NOV     NEXTPL,#CHARNO
00AA 83         538        RET
                539 ;
                540 ;*************************************************************
                541 ;
                542 ;PRINT  SUBROUTINE TO COPY H STRING OF BIT PATTERNS FROM ROM TO THE
                543 ;       DISPLRY REGISTERS.  STRING STARTS AT LOCATION P01NTED TO BY PNTR0.
                544 ;       CONTINUES UNTIL AN ESCAPE CODE (0FFH) IS REACHED.
                545 ;       NOTE THAT THE CHARACTER STRING PUT OUT MUST BE LOCATED ON THE SANE
                546 ;       PAGE AS THIS SUBROUTINE, SINCE SAME-PAGE MOVES ARE USED.
                547 ;       PRINT IN TURN CALLS EITHER SUBROUTINE 'WDISP' OR 'RENTRY'
                548 ;       TO ACTUALLY EFFECT WRITING INTO THE DISPLAY REGISTERS.
00AB F8         549 PPINT: MOV     A,PNTRB         ;LOAD NEXT CHARACTER LOCATION
00AC A3         559        MOVP    A,@A            ;LOAD BIT PATTERN INDIRECT
00AD C6B4       551        JZ      PRNT1           ;ESCRPE PATTERN
00AF 14D0       552        CALL    WDISP           ;OUTPUT TO NEXT CHARACTER POSITION
                553 ;##    (CALL   RENTPY          INSTEAD IF MESSAGE IS TO BE RIGHT JUSTIFIED!
00B1 18         554        INC     PNTR0           ;INDEX POINTER
00B2 04AB       555        JMP     PRINT
00B4 83         556 PRNT1  RET                     ;DONE
                557 ;
                553 ;*************************************************************
                559 ;
                560 ;JOHN   ARRAY HOLDS THE PIT PATTERNS FOR THE LETTERS 'JOHN' (SEE 'TEST2')
                561 ;       (NOTE THAT 'OHN' IS WRITTEN IN LOWER CASE LETTERS)
00B5            562 JOHN   EQU     $ AND BFFH
00B5 1E         563        DB      00011110B XOR SEGPOL
00B6 5C         564        DB      01011100B XOR SEGPOL
00B7 74         565        DB      01110100B XOR SEGPOL
00B8 54         566        DB      01010100B XOR SEGPOL
00B9 00         567        DB      00
                568 ;
                569 $EJECT
```

```
LOC  OBJ        SEQ        SOURCE STATEHENT

                570 ;*********************************************************
                571 ;
                572 ;ENCACC ENCODES LSNIBBLE OF ACC INTO HEX BIT PATTERN INTO ACC
00BA 530F       573 ENCACC: ANL     A,XENCHSK
00BC 03C0       574         ADD     A,#DGPATS
00BE A3         575         MOVP    A,@A
00BF 83         576         KET
                577 ;DGPHTS IS THE BASE FOR THE TABLE OF SEGMENT PATTERNS FOR THE BASIC
                578 ;DIGITS.  HERE THE FULL HEX SET (0-F) IS INCLUDED.
                579 ;FOR MANY USER APPLICATIONS, THE CHARACTER SET MAY BE WENDED OR AUGMENTED
                588 ;TO INCLUDE ADDITIONAL SPECIHL PURPOSE PATTERNS.
                581 ;FORMAT IS      PGFEDCBA        IN STANDARD SEVEN-SEGMENT ENCODING CONVENTION
                582 ;                               WHERE P REPRESENTS THE DECIMAL POINT
00C0            583 DGPATS  EQU     $ AND WFH
00C0 3F         584         DB      00111111B XOR SEGPOL
00C1 06         585         DB      00000110B XOR SEGPOL
00C2 5B         586         DB      01011011B XOR SEGPOL
00C3 4F         587         DB      01001111B XOR SEGPOL
00C4 66         588         DB      01100110B XOR SEGPOL
00C5 6D         589         DB      01101101B XOR SEGPOL
00C6 7D         590         DB      01111101B XOR SEGPOL
00C7 07         591         DB      00000111B XOR SEGPOL
00C8 7F         592         DB      01111111B XOR SEGPOL
00C9 67         593         DB      01100111B XOR SEGPOL
00CA 77         594         DB      01110111B XOR SEGPOL
00CB 7C         595         DB      01111100B XOR SEGPOL
00CC 39         596         DB      00111001B XW SEGPOL
00CD 5E         597         DB      01011110B XOR SEGPOL
00CE 79         598         DB      01111001B XW SEGPOL
00CF 71         599         DB      01110001B XOR SEGPOL
                600 ;
                601 ;*********************************************************
                692 ;
                603 ;WDISP  WRITES BIT PATTERN NOW IN ACC INTO NEXT CHARACTER POSITION
                604 ;       OF THE DISPLAY (NEXTPL).  ADJUSTS NEXTPL POINTER VALUE.
                605 ;       RESULIS IN DISPLAY BEING FILLED LEFT TO RIGHT, THEN RESTARTING
00D0 A9         606 WDISP:  MOV     PNTR1,A
00D1 FF         607         MOV     A,NEXTPL
00D2 8337       698         ADD     A #SEGMAP
00D4 29         609         XCH     A,PNTR1
00D5 A1         610         MOV     @PNTR1,A
00D6 EFDA       611         DJNZ    NEXTPL,WDISP1
00D8 BF08       612         MOV     NEXTPL,#CHARNO
00DA 83         613 WDISP1: RET
                614 ;
                615 $EJECT
```

```
LOC  OBJ        SEQ         SOURCE STATENENT

                616 ;*********************************************************
                617 ;
                618 ;RENTPY SUBROUTINE TO ENTER ACC CONTENTS INTO THE RIGHTMOST DIGIT
                619 ;       AND SHIFT EVERYTHING ELSE ONE PLACE TO THE LEFT
00DB B938       620 RENTRY: MOV     PNTR1,#SEGMAP+1
00DD BF08       621         MOV     NEXTPL,#CHARNO
00DF 21         622 RENTR1: XCH     A,@PNTR1
00E0 19         623         INC     PNTR1
00E1 EFDF       624         DJNZ    NEXTPL,RENTR1
00E3 BF08       625         MOV     NEXTPL,#CHARNO  ;POINT TO LEFTMOST CHARACTER
00E5 83         626         RET
                627 ;
                628 ;*********************************************************
                629 ;
                630 ;RDPHDD TOGGLE DECIMAL F'OINT IN LAST CHARACTER DISPLAY CHARACTER
                631 ;DPADD  TOGGLES DECIMAL F'OINT IN THE CHARACTER POINTED TO BY THE ACC
                632 ,
00E6 2301       633 RDFHDD: MOV     A,#01H          ;SET INDEX TO RIGHTMOST POSITION
00E8 0337       634 DPADD:  ADD     A,#SEGMAP       ;ACCESS DISPLAY REGISTER FOR DESIRED PLACE
00EA A9         635         MOV     PNTR1,A
00EB F1         636         MOV     A,@PNTR1
00EC D380       637         XRL     A,#80H
00EE A1         638         MOV     @PNTR1,A
00EF 83         639         RET
                640 ,
                641 ;*********************************************************
                642 ;
                643 ;HOLD   SUBROUTINE CALLED WHEN KEY IS KNOWN TO BE DOWN.
                644 ;       WILL NOT RETURN UNTIL KEY IS RELEASED.
00F0 D5         645 HOLD:   SEL     RB1
PBFI FE         646         MOV     A,LASTKY        ;<LASTKY>=0FFH IFF NO KEYS DOWN
00F2 C5         647         SEL     RB0
00F3 37         648         CFL     A
00F4 96F0       649         JNZ     HOLD
00F6 83         658         RET
                651 ;
                652 ;*********************************************************
                653 ;
                654 ;DELAY  SUBROUTINE HANGS UP FOR THE NUMBER OF COMPLETE DISPLAY SCANS EQUAL
                655 ;       TO THE CONTENTS OF THE ACCUMULATOR WHEN CALLEG.
00F7 B923       €56 DELAY:  MOV     PNTR1,#RDELAY
00F9 A1         657         MOV     @PNTR1,A
SOFA F1         658 DELAY1: MOV     A,@PNTR1
00FB 96FA       659         JNZ     DELAY1
00FD 53         660         RET
                661 $EJECT
```

```
LOC  OBJ          SEQ         SOURCE STATEMENT

0100              662          100H
                  663 ;
                  664 ;*********************************************************
                  665 ;
                  666 ;THE CODE ON THIS PAGE IS FOP DEMONSTRATION PURPOSES ONLY-
                  667 ;I TRUELY DOUBT WHETHER ANY END USERS WOULD LIKE TO SEE A NAME
                  668 ;POPPING UP ON THEIR CALCULATOR SCREENS.
                  669 ;HOWEVER, THE CODE SHOWN HERE DOES INDICATE HOW THE UTILITY SUBROUTINES
                  679 ;INCLUDED HERE COULD BE ACCESSED.
                  671 ;THE ROUTINES THEMSELVES HUE CALLED WHEN ONE OF THE FOUR BUTTONS
                  672 ;ON THE RIGHT-HAND SIDE OF THE PROTOTYPE KEYBOARD IS PRESSED.
                  673 ;
                  674 ;*********************************************************
                  675 ;
                  676 ;FUNCTN ROUTINE TO IMPLEMENT ONE OF FOUR DEMO UTILITIES, ACCORDING
                  677 ;       TO WHICH OF THE FOUR FUNCTION KEYS WAS PRESSED
0100 1212         678 FUNCTN: JB0     FUNCT1
0102 320E         679         JB1     FUNCT2
0104 520A         680         JB2     FUNCT3
                  681 ;
0106 14E6         682 FUNCT4: CPLL    RDPADD
0108 0477         683         JMP     ECHO
                  684 ;
010A 342E         685 FUNCT3: CKL     TEST3
010C 0477         686         JMP     ECHO
                  687 ;
010E 3424         688 FUNCT2: CHLL    TEST2
0110 0477         689         JMP     ECHO
                  690 ;
0112 3416         691 FUNCT1: CALL    TEST1
0114 0477         692         JMP     ECHO
                  693 ;
                  694 ;*********************************************************
                  695 ;
                  696 ;TEST1  CODE SEGMENT TO FILL DISPLAY REGISTERS WITH DIGITS DOWN TO '1'
0116 BF08         697 TEST1:  MOV     NEXTPL,#CHARNO
0118 B808         698         MOV     PNTR0,#CHARNO   ;SET FOR EIGHT LOOP REPETITIONS
011A FF           699 TST11:  MOV     A,NEXTPL
011B 14BA         700         CALL    ENCACC
011D 14D0         701         CALL    WDISP
011F E81A         702         DJNZ    PNTR0,TSTII     ;COPY NEXT DIGIT INTO DISPLAY REGISTERS
0121 BF08         703         MOV     NEXTPL,#CHARNO
0123 83           704         RET
                  705 ;
                  786 $EJECT
```

```
 LOC  OBJ        SEQ        SOURCE STATEMENT

                 707 ;*********************************************************
                 708 ;
                 789 ;TEST2  WRITES THE SEGMENT PATTERN FOR 'JOHN' ONTO THE DISPLAY.,
                 718 ;       WAITS FOR A WHILE, AND THEN CLEARS THE DISPLAY
 0124 B8B5       711 TEST2:  MOV     PNTR0,#JOHN
 0126 14AB       712         CALL    PRINT
 0128 2364       713         MOV     A,#100  ;SCW DISPLAY FOR 100 CYCLES
 012A 14F7       714         CALL    WLAY
 012C 049E       715         JMP     CLEAR
                 716 ;
                 717 ;*********************************************************
                 718 ;
                 719 ;TEST3  SUBROUTINE TO FILL DISPLAY WITH DASHES
                 728 ;       JUMPS INTO SUBROUTINE 'CLEAR'
                 721 ;       AS SOON AS THE KEY IS RELEASED.
 012E 2340       722 TEST3:  MOV     A,#01000000B XOR SEGPOL ;PATTERN FOR '-'
 0130 14A0       723         CALL    FILL
 0132 14F0       724         CALL    HOLD
 0134 049E       725         JMP     CLEAR
                 726 ;
                 727 ;*********************************************************
                 728 ;
                 729 END

USER SYMBOLS
ASAVE  0002    BLANK  0000    CHARNO 0008    CHRPOL 0000    CHRSTP 0057    CLEAR  009E    CLR1   00A4    CURDIG 0007
DEBNCE 0004    MLAY   00F7    DELAY1 00FA    DGPATS 00C0    DPADD  00E8    ECHO   0077    ENCACC 00BA    ENCMSK 000F
FILL   00A0    FKEY   0081    FUNCT1 0112    FUNCT2 010E    FUNCT3 010A    FUNCT4 0106    FUNCTN 0100    HOLD   00F0
INIT   0060    INPMSK 00F8    JOHN   0085    KBDBUF 0022    KBDIN  0083    KEYLOC 0021    LASTKY 0006    LEGNDS 008E
NCOLS  0004    NEGLOG 00FF    NEXTPL 0007    NREPTS 0020    NROWS  0004    NXTLOC 0023    PDIGIT 8610    PINPUT 0009
PNTR0  0000    PNTR1  0001    POSLOG 0000    PRINT  00AB    PRNT1  00B4    PSGMNT 0008    RDELAY 6023    RDPADD 00E6
REFR1  0013    REFRSH 0010    RENTR1 00DF    RENTRY 00DB    ROTCNT 0005    ROTPAT 0004    SCAN   001E    SCAN1  6821
SCAN3  m34     SCAN5  003F    SCAN6  0045    SCAN8  004F    SCAN9  8057    SEGMAP 0037    SEGPOL 0000    TEST1  0116
TEST2  8124    TEST3  012E    TICK   FFF0    TIINT  0007    TIRET  000E    TST11  011A    WDISP  00D0    WDISP1 00DA

ASSEMBLY COMPLETE,  NO ERRORS
```

```
ASAVE   202#  249   269
BLANK   1791  280   531
CHARNO  1731  220   405   441   533   537   612   621   625   697   698   703
CHRPOL  169#  429   430   431   432   433   434   435   436
CHRSTB  282   428#
CLEAR   449   531#  715   725
CLR1    534#  536
CURDIG  206#  283   289   395   405   441
DEBNCE  178#  370
DELAY   6561  714
DELAY1  6581  659
DGPATS  574   583#
DPADD   6341
ECHO    465#  471   683   686   689   692
EHCACC  469   573#  700
ENCMSK  183#  573
FILL    5321  723
FKEY    466   473#
FUNCT1  678   691#
FUNCT2  679   688#
FUNCT3  680   685#
FUNCT4  6821
FUNCTN  473   678#
HOLD    6451  649   724
INIT    236   440#
INPMSK  1711  446
JOHN    5621  711
KBDBUF  2141  386   442   490
KBDIN   465   490#  493
KEYLOC  2131  300   389   444
LASTKY  205#  359   360   385   408   646
LEGNDS  494   508#
NCOLS   175#  328
NEGLOG  167#
NEXTPL  1931  533   536   537   607   611   612   621   624   625   697   699   703
NREPTS  2121  361
NROWS   1741
NXTLOC  3291  392
PGIGIT  1581  285
PINPUT  160#  301   447
PNTR0   1911  300   358   361   370   380   383   386   387   389   390   406   442   443   444   445
        549   554   698   702   711
PNTR1   1921  290   291   417   418   421   490   492   532   534   535   606   609   610   620   622
        623   635   636   638   656   657   658
POSLOG  1661  169   170
PRINT   549#  555   712
PRNT1   551   556#
PSGMNT  1591  281   292
RDELAY  216#  417   656
RDPADD  633#  682
REFR1   282#
REFRSH  269   280#
RENTR1  622#  624
PEYTRY  479   620#
```

```
ROTCNT  204#  328   392
ROTPAT  203#  330   391
SCAN    300#
SCAN1   328#
SCAN3   362   380#
SCAN5   331   371   381   384   389#
SCAN6   395#
SCAN8   407   409#
SCAN9   395   419   423#
SEGMAP  220#  288   532   608   620   634
SEGPOL  170#  280   531   563   564   565   566   584   585   586   587   588   589   590   591   592
        593   594   595   596   597   598   599   722
TEST1   691   697#
TEST2   688   711#
TEST3   685   722#
TICK    177#  250   451
TIINT   248#
TIRET   269#
TST11   699#  702
WDISP   552   606#  701
WDISP1  611   613#
```

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La Tour d'Asnieres
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Berkeley 94704
Tel: (415) 843-7625

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Cupertino 95014
Tel: (408) 257-9880

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